Spatial Coherence of Nonlinear, Nonstationary, Non-Gaussian Ocean Waves on a One-Mile Scale From Scanning Radar Altimeter

Leon E. Borgman
L. E. Borgman, Inc., 2526 Park Avenue
Laramie, WY 82070
Phone: (307) 742-3178 Fax: (307) 742-2583 Email: borgman@cyberhighway.net
http://faculty.gg.uwyo.edu/borgman

Ronald W. Marrs
Department of Geology and Geophysics
University of Wyoming, Laramie, WY 82071
Phone: (307) 766-2320 Fax: (307) 766-6679 Email: rwmarrs@uwyo.edu
http://www.uwyo.edu/A&S/geol/faculty/marrs.htm

Edward J. Walsh
NASA Goddard Space Flight Center
1505 Mapleton Avenue, Boulder, CO 80304
Phone: (303) 497-6357 Fax: (303) 497-6181 Email: walsh@osb.wff.nasa.gov
http://SRA.remote.sensing.org
Award Nos. N00014-98-C-0206 and N00014-98-F-0209

LONG-TERM GOAL

The lack of good ocean surface data on the one-mile scale is a major stumbling block for proper evaluation of proposed Mobile Offshore Base (MOB) conceptual designs. A general model and associated software for stationary, linear, statistical, directional wave systems have been available for some time. If that model can appropriately be used for design of marine mega-structures, then there is no problem in proceeding with conceptual MOB designs and their evaluations. However, it is known that storm waves are nonlinear to some extent. The major goal is the determination of the accuracy of the linear approximation and the type of nonlinear feature present in severe storm waves.

OBJECTIVES

Many frustrations and uncertainties would disappear if adequate data on the proper spatial scale were available to serve as a basis for selection of design criteria. This project is designed to examine and analyze NASA scanning radar altimeter data collected by Ed Walsh.

APPROACH

Walsh has recorded SRA data in flights over storm wave systems near Australia and is in the process of collecting data for Atlantic storms (1998 and 1999 hurricane seasons). In the present project, these data are being analyzed and summarized graphically in a “design engineer's atlas of storm wave measurements". The atlas includes various statistical studies that address the linear/nonlinear balance in severe storm waves.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 1999**	2. REPORT TYPE	3. DATES COVERED **00-00-1999 to 00-00-1999**
4. TITLE AND SUBTITLE **Spatial Coherence of Nonlinear, Nonstationary, Non-Gaussian Ocean Waves on a One-Mile Scale From Scanning Radar Altimeter**		5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **L. E. Borgman, Inc,2526 Park Avenue,Laramie,WY,82070**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR’S ACRONYM(S) 11. SPONSOR/MONITOR’S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release; distribution unlimited**		
13. SUPPLEMENTARY NOTES		
14. ABSTRACT		
15. SUBJECT TERMS		

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**6**	

WORK COMPLETED

The work this year consisted of developing methodology and algorithms, and related software. Although most of the data processing is planned for the second year, a moderate amount of pre-existing measurements and one section of Hurricane Bonnie data (1998) were analyzed.

RESULTS

The most interesting results were obtained from an analysis of a limited amount of data from Hurricane Bonnie that became available during this year. Some of the findings are summarized below.

Water Level Cumulative Histogram: After elimination of obvious measurement defects and artifacts, the cumulative histogram of water level deviations from mean water level was developed as shown in Fig. 1, plotted on "straight-line" normal probability paper. The data lie almost exactly on the line, except for the top 0.25% of values. The almost straight line normal graph supports the conjecture that the storm seas in Bonnie act approximately as a Gaussian process, which is certainly consistent with linear statistical wave theory. Of course this is just one analysis, and further confirmation from other hurricane data will be needed to confirm or disprove this conclusion.

Crest and Trough Length Statistics for Bonnie: A section of the contoured elevations for Bonnie is shown in Fig. 2. Wave crests and troughs extend nearly across the strip which is about 1100 meters wide. The crests and troughs are diagonal (about 45º) to the flight direction. Thus, a crest with a 45º orientation would have a length about $\sqrt{2}$ times 1100 meters, or about 1540 meters. This is very nearly the length of a one-mile long MOB.

The data from Bonnie, thus demonstrates that a more or less continuous large wave crest stretching the full length of the MOB can develop in even an intermediate hurricane such as Bonnie. The trough-to-crest height at the most severe wave is about 16 meters or 52 feet.

Crest and Trough Length Statistics: The following algorithm for crest and trough length seems to work reasonably well for flights in the direction of wave travel.

1. Each of the 64 grid lines in the direction of flight are searched for all elevations which are larger than the preceding and succeeding elevations along the line, and which are in the upper p-fractile of the elevations. The values 0.20 or 0.25 seemed to work pretty well for p. The restriction to the larger elevations keeps out many insignificant maxima from low wave activity.

2. Each maxima from Step #1 was grouped with any other such maxima lying within a distance of "PixelSep". This produced clusters of maxima which were reasonably contiguous with each other. A value of 3, 4, or 5 seemed to work for "PixelSep", depending on the pixel separation distance.

3. Finally, a straight line was fit through each cluster and terminated at each end at the outermost projection of the cluster elements onto the line. This line segment was defined to be a crest line.

The trough lines were similarly defined using minima. The resulting crest and trough lines are drawn on top of the previous figure, together with a color-coded scatter plot of crest and trough elevations. This is shown in Fig. 3.

A scatter plot of the crest line and trough line length and orientation in the Bonnie data, on polar coordinates, is given in Fig. 4. The outer circle radius scale of 1600 meters is very nearly the MOB length of one mile.

IMPACT/APPLICATION

If the conjecture that hurricane waves behave, at least locally, approximately as a Gaussian process can be verified, it will have a major effect on future MOB design practices. The substantial methodology from linear statistical wave theory used by many engineers in the petroleum industry, could be carried over to the MOB-scale structures, with some assurance of validity.

TRANSITIONS

The preliminary analyses and the emerging definitions of crest and trough lines in 2-D sea surfaces were presented at the conference on very large floating structures (VLFS '99) in Hawaii, September 1999. The subsequent informal discussions provided a healthy dialogue on questions related to such investigation and should lead to an increased awareness of problems and analysis procedures for studies of this type.

PUBLICATIONS

Borgman, L. E.; Marrs, R. W.; Reif, S. L.; and Walsh, E. J. (1999), Storm wave topography: Creating a design engineer's atlas of realistic sea surface features from SRA measurements, *Proceedings of the 3rd International Workshop on Very Large Floating Systems (VLFS '99)*, University of Hawaii, Honolulu, Hawaii, September 22-24, 9-2-2.

Walsh, E. J.; Vandemark, D.; Wright, C. W.; Swift, R. N.; Scott, J. C.; and Hines, D. E. (1999), Measuring directional wave spectra and wind speed with a scanning radar altimeter, *Proceedings of the IEEE International Geoscience and Remote Sensing Symposium (IGARSS '99)*, Hamburg, Germany, June 28-July 2, CC09_15:30.

Wright, C. W.; Walsh, E. J.; Vandemark, D. C.; Krabill, W. B.; and Garcia, A. W. (1999), Hurricane directional wave spectrum measurement with a scanning radar altimeter, *Proceedings of the 3rd International Workshop on Very Large Floating Systems (VLFS '99)*, University of Hawaii, Honolulu, Hawaii, September 22-24, 9-1-3.

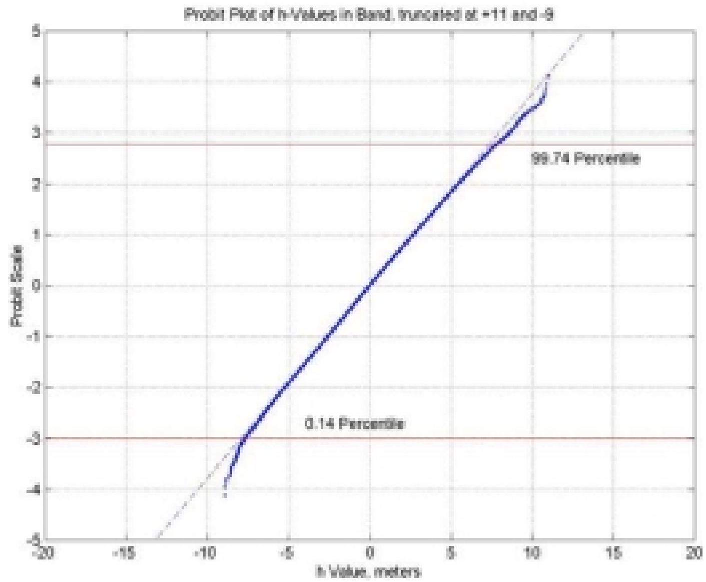

Figure 1

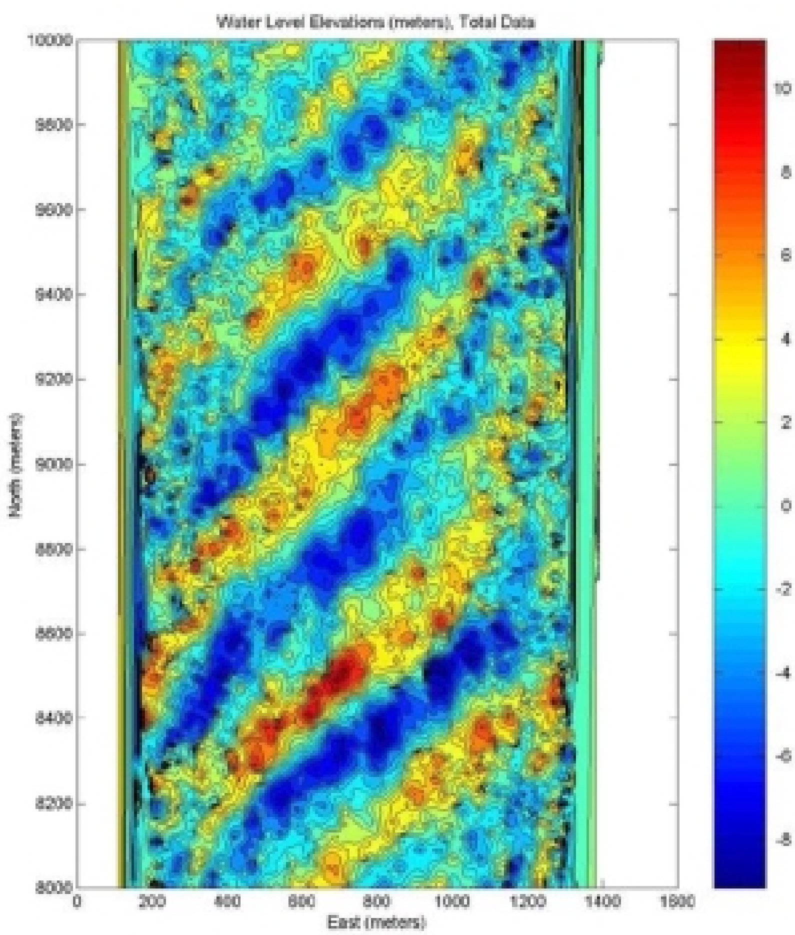

Figure 2

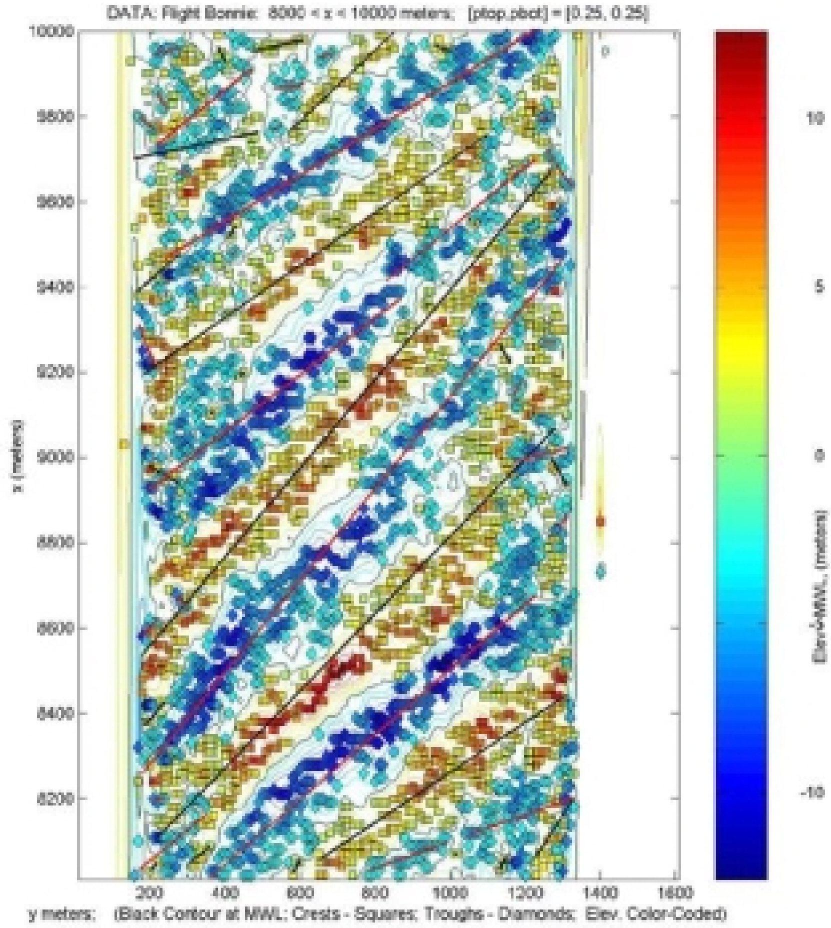
DATA: Flight Bonnie: 8000 < x < 10000 meters: [ptop,pbot] = [0.25, 0.25]
x (meters)
y meters: (Black Contour at MWL; Crests - Squares; Troughs - Diamonds; Elev. Color-Coded)
Elev-MWL (meters)

Figure 3

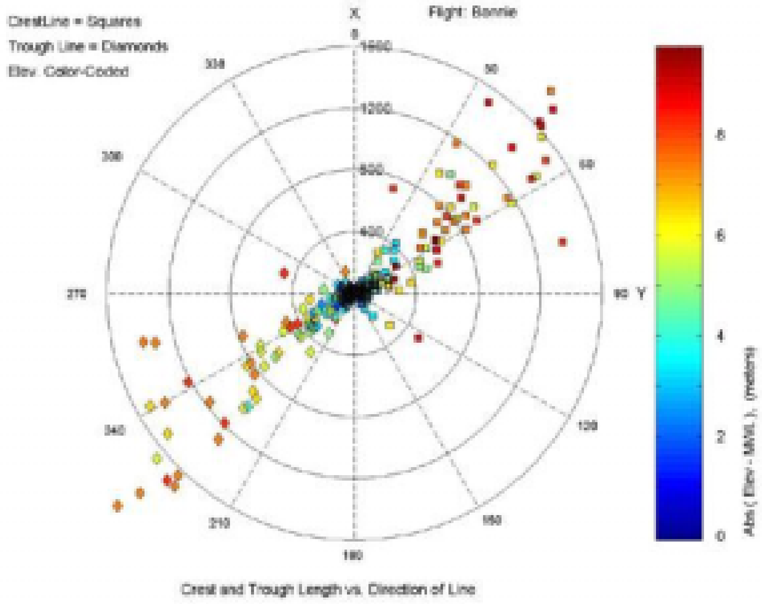
CrestLine = Squares
Trough Line = Diamonds
Elev. Color-Coded
X
Flight: Bonnie
1600
1200
800
400
90
Y
180
Abs (Elev - MWL), (meters)
Crest and Trough Length vs. Direction of Line

Figure 4